Río Blanco Formation

UNITED STATES GEOLOGICAL SURVEY

quadrangle. Thanks are also extended to Rigoberto Reynoso, formerly resident geologist with Bear Creek Mining Company in Lares, Puerto Rico, who gave freely of his time in discussing the many problems encountered in the field.

STRATIGRAPHY AND MINERALOGY OF VOLCANOGENIC ROCKS The general characteristics of the individual formations have been outlined in some detail elsewhere (Nelson and Tobisch, 1967; McIntyre and others, 1970), and only certain noteworthy aspects of the volcanogenic rocks will be dis-

The volcanogenic rocks in the quadrangle are divided into two parts separated by the Añasco fault. The Río Blanco Formation and Concepción Formation (McIntyre and others, 1970) lie south of the fault; the Mal Paso, Río Culebrinas (McIntyre and others, 1970), Milagros, and Matilde Formations (Nelson and Tobisch, 1967) lie to the north. Rocks south of the fault range in age from Late Cretaceous to early Tertiary (Eocene), and are characterized by incipient greenschist facies metamorphism; those to the north are early Tertiary in age and are characterized by incipient zeolite facies metamorphism. Concepción and Río Blanco Formations.—The Concepción Formation is characterized by lava flows and thinbedded volcaniclastic sedimentary rocks. The Río Blanco Formation consists chiefly of massive tuff-breccia and lapilli tuff. Both formations are andesitic to dacitic in com-The rocks have been recrystallized, and primary textures

and minerals are generally modified to varying extent. Plagioclase, hornblende, and clinopyroxene are the typical primary minerals in rocks of both formations. The proportions of these minerals vary greatly, but plagioclase, along with optically unresolvable material, is generally dominant and forms the bulk of the rock. Plagioclase ranges from albite to andesine, but commonly is altered to epidote or clay minerals(?). The primary plagioclase was undoubtably more calcic than albite, but recrystallization has yielded the more sodic varieties. Where present, hornblende and pyroxene are also generally altered to varying extent. Principal secondary minerals which commonly make up nearly half the rock, include epidote minerals, chlorite, calcite, sericite(?) and quartz. These minerals generally form pseudomorphs after the primary minerals. Prehnite and, rarely, laumontite have also been observed.

formations north of the fault by its red-purple color as well as by its mineralogy. Tuff breccias, lapilli tuffs and lava flows of the Mal Paso Formation are highly scoriaceous. The vesicles are commonly filled with calcite, quartz, zeolite minerals(?) and bright-green celadonite(?). The tuff breccia and lapilli tuff are deeply weathered, and could not be sampled for thin section analysis. Thin sections of vesicular lava flows show calcic plagioclase, however, and this evidence coupled with chemical analysis indicates the rock is a basalt. Another rock type which occurs in the Mal Paso Formation along Highway 119, may be a lava flow, sill, or dike. It shows a porphyritic texture in thin section, with a groundmass of albite microlites, magnetite and (lesser) hematite in which are set large crystals (sometimes glomeroporphyritic) of albite  $(A_{0-2})$  and some bipyramidal crystals of primary quartz that show slightly corroded crystal boundaries. Accessory minerals are calcite, apatite and rare epidote. This rock has some mineralogical, textural, and chemical (8.2 percent Na<sub>2</sub>O) characteristics of a quartz keratophyre (Williams and others, 1955), and may be genetically related to chemically similar lavas and dikes found in the Concepción Formation.

Río Culebrinas, Milagros and Matilde Formations.— The Río Culebrinas, Milagros and Matilde Formations consist of thin-bedded tuffs and fine- to medium-grained volcanic sandstones and massive tuff breccias. Lava flows tion. They contain plagioclase (commonly calcic labradorite, but ranging from andesine to bytownite), hornblende,

and pyroxene in varying amounts. Primary quartz is relatively common in the Río Culebrinas Formation, but is found only in sparse amounts in the Milagros and Matilde Formations. Many of the thin-bedded tuffs in the Río Culebrinas Formation contain crystal fragments of plagioclase, pyroxene and hornblende, along with lapilli-sized fragments of plagioclase-, hornblende-, or pyroxene-bearing porphyry. Optically unidentifiable fragments, and rarely pumice, are other rock constituents. The plagioclase in the rocks is commonly slightly to moderately altered to clay minerals(?). The pyroxene in rocks of these three formations is typically a colorless clinopyroxene; however, in the Milagros Formation, especially in the breccia member, both orthopyroxene and clinopyroxene coexist in the same rock. Secondary minerals include laumontite, heulandite, analcime, celadonite(?), chlorite, quartz, stilpnomelane, calcite and rare epidote, which range in volume up to several per-

cent from specimen to specimen. Age.—A limestone lens from the Río Blanco Formation located in the bed of the Río Mayagüecillo approximately 50-75 meters south of the quadrangle boundary yielded poorly preserved specimens of *Pseudorbitoides* sp., which is a Late Cretaceous fossil (K. N. Sachs, Jr., 1967, oral commun.; see also Mattson, 1960). No recognizable fossils were found in the Concepción Formation. To the west in the Central la Plata quadrangle, however, the Concepción Formation conformably underlies the Mal Paso Formation (McIntyre and others, 1970). Since the base of the Mal Paso is interleaved with the top of the Concepción, and is middle Eocene (McIntyre and others, 1970), the Concepción Formation is surely no older than Eocene. All the formations north of the Añasco fault are early Tertiary in age. Fossils from the Matilde, Río Culebrinas and Mal Paso Formations yield a middle Eocene age (McIn-

tyre and others, 1970). The Milagros Formation, which lies

between the Río Culebrinas and Matilde Formations, is

most probably also middle Eocene.

INTRUSIVE ROCKS The Concepción and, to a lesser extent, the Río Blanco Formations have been intruded by small diorite and quartz diorite bodies ranging in size from dikes a few meters or more across to stocks nearly a kilometer across. In the eastern part of the Concepción Formation, these igneous bodies appear to have a close spatial (and possibly genetic) relationship to the lava flows. Chemical analysis of one lava flow (or dike?) from the Concepción Formation showed a high content of Na<sub>2</sub>O (6.3 percent), but this may not be typical of the lavas. Often the textural variation between intrusive bodies and lava flows in this area is so erratic that, coupled with poor exposure, it is not practical to map the intrusive bodies separately.

The mineralogy of the intrusive bodies consists essentially of plagioclase, hornblende and, rarely, clinopyroxene. Plagioclase (andesine) is the predominant primary mineral, and is moderately to strongly altered. The hornblende is colorless to pale green and may be in part an alteration product of primary hornblende or pyroxene. Clinopyroxene, however, has been observed only in one small plug within the Río Blanco Formation. Secondary minerals of the intrusive bodies include epidote, chlorite, calcite and rarely, prehnite. Pyrite and magnetite are common accessories, but within the general area of Barrio Purisima Concepción, pyrite often occurs disseminated throughout the intrusive bodies in larger amounts than is generally found

TECTONIC STRUCTURES

to be little deformed, although there is some evidence that faulting may offset the Lares Limestone in the Río Guatemala north of San Sebastián (W. H. Monroe, 1967, written commun.) and in the Río Guajataca northwest of Lares; minor faulting occurs elsewhere. The extraordinary topographic lineations in the Lares Limestone (note the distinct geomorphic features north of Lares; see Monroe, 1964, p. B126-B129) that strike northwest and, to a lesser degree, northeast are noteworthy. It is possible that the principal structural directions of the underlying volcanogenic rocks, which also trend northwest with subordinate northeast directions, have influenced the directions of joint pattern formation in the limestone (compare Hodgson, 1965). The Upper Cretaceous and lower Tertiary rocks have a general northwest strike and their dip is generally north (south of the Añasco fault) or south (north of the Añasco fault), as shown in section B-B'. The Río Blanco, the eastern part of the Concepción, and the Milagros Formations do not show much structural (tectonic) complication. This may be due to the sluggish response of the massive formations to internal deformation, as well as to the lack of marker horizons to record the deformation. On the other hand, the thin-bedded rocks in the western part of the Concepción, Mal Paso and Río Culebrinas Formations show considerable deformation, which may be, at least in part, related to movement along the Añasco fault.

The Añasco fault and its subsidiary faults are the most prominent structural features in the quadrangle. They cut across the strike of both Upper Cretaceous and lower Tertiary formations. Evidence for apparent sense of horizontal movement along the Añasco fault in the San Sebastián quadrangle is equivocal. To the west in the Central la Plata quadrangle, however, the overall apparent horizontal movement along the Añasco fault appears to be left lateral (D. H. Mal Paso Formation.—The Mal Paso Formation occurs McIntyre, 1967, oral commun.); a component of vertical movement is also likely. The dip of the Añasco fault plane in the San Sebastián quadrangle was determined by measuring shear surfaces in the fault zone. These surfaces have a consistently steep southward dip of 60° to 70° across the quadrangle. The large fault just to the north has a steeper dip, probably between 80° and 90°. Other faults in the quadrangle appear to be essentially vertical.

brings Formation. The folds plunge 5° to 30° to the northwest in most areas, but in the general area of Quebrada Las Cañas, individual folds locally reverse their plunge, alternating between northwest and southeast. If marker horizons were available, they would delineate elongate basins, domes and other culmination patterns. These doublyplunging structures may have been formed by variations in compressive strain causing the fold axes to buckle (Sitter, 1964, p. 257–258; Ramsay, 1962, fig. 19). One of the more enigmatic structures occurs between the Mal Paso Formation and the large anticline to the north. The structure is defined by a zone of disturbance in which the bedding orientation is highly erratic over short distance, and by graded bedding with tops toward the center of the disturbed zone on both sides. These facts suggest that the structure is an overturned syncline which may have sustained a certain amount of rupture parallel to its axial plane in such a way that the movement was distributed over a wide disturbed zone. The syncline is nearly isoclinal in the east (section B-B'), but grades to a tight style toward the west These rocks are typically andestic to dacitic in compositions (section A-A'). In the Central la Plata quadrangle, the structure reverts to a normal upright syncline and has an

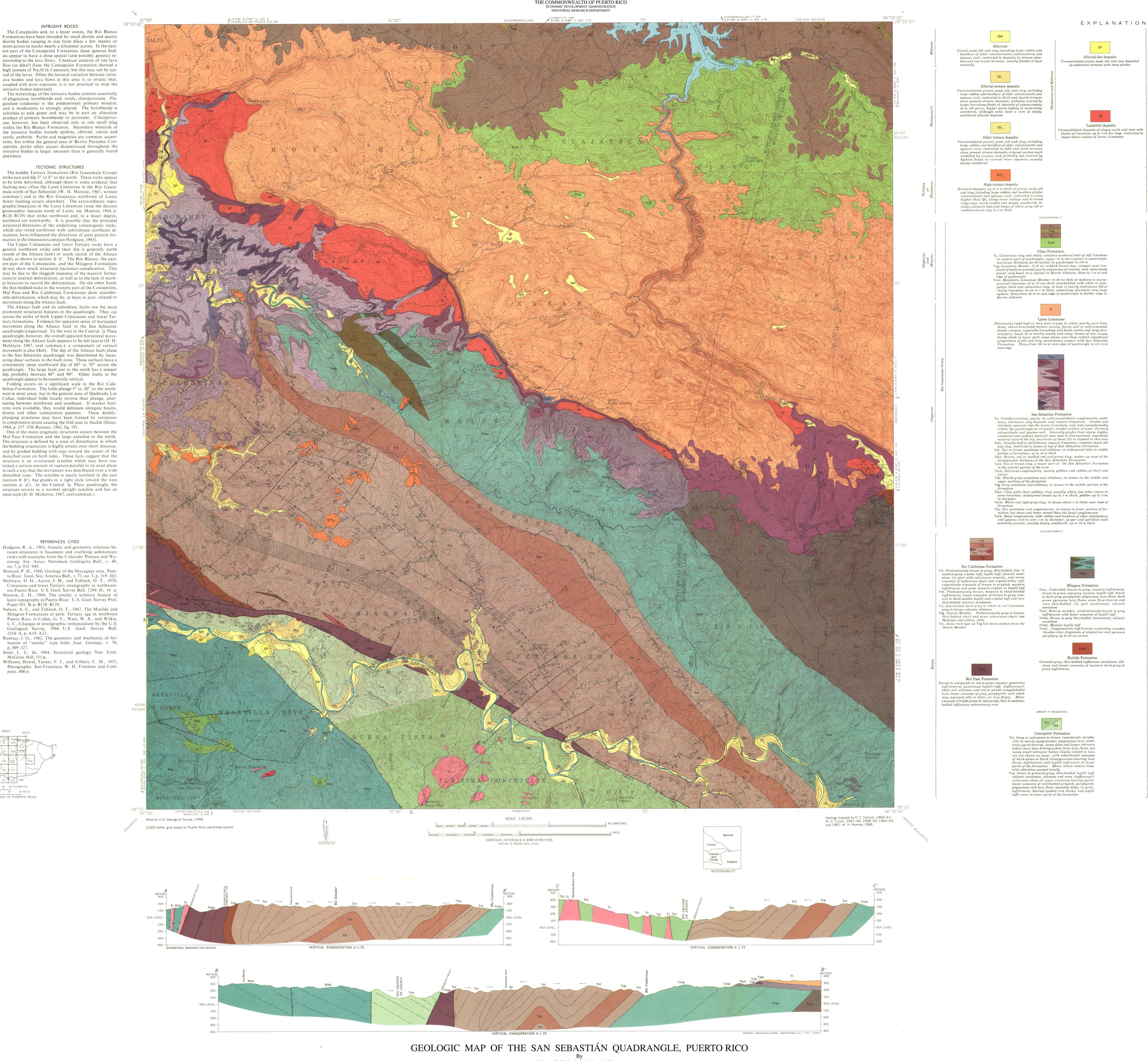
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0 10 20 30 40 50 KILOMETERS INDEX TO GEOLOGIC MAPPING IN PUERTO RICO



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QUESTIONABLE FAULT CONTACT

Kbb, Pale-green to dark-green, yellowish-green, and purple, massive lapilli tuff and tuff-breccia; porphyritic dikes and some flow breccia occur locally. Massive dark clinopyroxene-bearing lava flows and plagioclase-rich lava flows occur near top of the formation. Plagioclase-rich lava flows are indistinguishable from dikes in most exposures Kbt, Brown, thin-to thick-bedded, locally fissile volcanic sandstone, silt-INTRUSIVE ROCKS

Ti, Dark-green to green porphyritic diorite grading to pale-gray, mediumgrained equigranular hornblende-quartz diorite and diorite. These rocks commonly bear pyrite. Intrusive bodies within lava-rich portion of the Concepción Formation (TcI) frequently change texture rapidly over short distances, and distinguishing between porphyritic lava flows and porphyritic intrusive rocks becomes impractible Tic, Intrusive plug bearing clinopyroxene and hornblende

Zone of disturbed beds Contact

Long dashed where approximately located, short dashed where inferred queried where existence uncertain <u>→ 0</u> ------Long dashed where approximately located, short dashed where inferred, queried where existence uncertain. U, upthrown side; D, downthrown side. Arrows show relative horizontal movement

Showing crestline and direction of plunge. Dashed where approximately located, queried where existence uncertain <del>\*\*</del>?-?-

Inclined Overturned Vertical Horizontal Strike and dip of beds

Showing troughline and direction of plunge. Dashed where

approximately located, queried where existence uncertain

Inclined Overturned Strike and dip of beds

Top of beds indicated by graded bedding Strike and dip of shear foliation in fault zone

Bearing and plunge of slickenside

Bearing and plunge of axis of small fold

Showing sense of movement of fold

Direction of top of beds

Shown in section only

Strike and dip of axial plane of small fold

Ts, Undifferentiated; poorly - to well-consolidated conglomerate, sandtones, siltstones, clay deposits and impure limestone. Grades and interbeds upwards into the Lares Limestone, and rests unconformably within the quadrangle on irregular, eroded surface of lower Tertiary volcaniclastic and igneous rock. Generally grades from course, highlyweathered and oxidized material near base to finer-grained, unoxidized material toward the top, maximum of about 225 m exposed in this area TsIs, Usually buff to dark-brown impure limestone; contains much silt and clay; restricted to lenses at top of San Sebastián Formation Tst, Tan or brown sandstone and siltstone; in widespread beds in middle Tscr, Brown, red or mottled red and green clay; makes up most of the stratigraphic thickness of the San Sebastián Formation Tsct, Tan or brown clay, a major part of the San Sebastián Formation Tscq, Siliceous conglomerate, mostly pebbles and cobbles of chert and Tsb, Bluish-gray sandstone and siltstone; in lenses in the middle and Tsg, Gray sandstone and siltstone; in lenses in the middle portion of the Tscc, Clay with chert pebbles; clay usually white, but other colors at some localities; widespread lenses up to 2 m thick, pebbles up to 5 cm

> Tmu, Undivided; brown to gray, massive tuff-breccia, brown to green and gray massive lapilli tuff, brown to dark gray porphyritic plagioclase lava flows, dark green pyroxene lava flows, some flow-breccia and rare thin-bedded (in part pumiceous) volcanic mb, Breccia member; predominantly brown to gray tuff-breccia with lesser amounts of lapilli tuff Imbs, Brown to gray thin-bedded (pumiceous) volcanic Tmbl, Conglomeratic tuff-breccia containing rounded (boulder-like) fragments of plagioclase and pyroxene

Matilde Formation Greenish-gray, thin-bedded tuffaceous sandstone, siltstone and lesser amounts of massive dark gray to

Othmar T. Tobisch and Mort D. Turner